INSTRUCTIONS

FOR

INFILTRATION SURVEYS

FLOOD CONTROL

COORDINATING COMMITTEE

July 1939

Prepared By
Infiltration Sub-Committee

UNITED STATES DEPARTMENT OF AGRICULTURE
FLOOD CONTROL COORDINATING COMMITTEE

Washington

MEMORANDUM NO. 45

July 28, 1939

MEMORANDUM FOR FIELD FLOOD CONTROL COORDINATING COMMITTEES:
(Through B.A.E., F.S., and S.C.S.)

Subject: Instructions for infiltration surveys.

Memorandum No. 43 of July 12, 1939, covering the subject "Shipments of infiltration apparatus" states "Instructions on their use prepared by the special committee... will be sent you within the next few days." Enclosed herein are Instructions for Infiltration Surveys which were approved by the Flood Control Coordinating Committee on July 26, 1939.

These instructions should be followed by all infiltration survey parties. Difficulties that arise in the field or any suggestions for improvement in methods or apparatus will be brought to the attention of the infiltration sub-committee through the usual bureau channels.

FLOOD CONTROL COORDINATING COMMITTEE

By Arthur C. Ringland
Arthur C. Ringland, Chairman.

Attachment.

INSTRUCTIONS FOR INFILTRATION SURVEYS

Contents

INSTRUCTIONS FOR INFILTRATION SURVEY

Purposes of the infiltration survey.- The infiltration survey is designed to accomplish a number of separate objectives. These include:

A. The determination of the infiltration rates of areas which are comparatively homogeneous with respect to soil, land use, and topography.

B. The location of flood source areas.

C. The location of areas in which control of flood water may best be achieved through the use of structures or mechanical measures.

D. The location of areas potentially susceptible of improvement by changed land use practices.

E. Development of data adaptable to a more complete hydrologic analysis of the primary and secondary drainage areas.

By infiltration index is meant the maximum rate of water intake by a soil when it is in a stated condition of structure, moisture content, or other modifying condition. However, with respect to the procedures hereinafter described infiltration is essentially the difference between total rainfall and total run-off and infiltration index is the difference between average rates of rainfall and run-off during the 20 minute period after run-off has reached a constant or nearly constant rate. This is more fully explained later in these instructions. Thus, for the purposes of the infiltration survey of watersheds by means of the North Fork infiltrometer no attempt will be made to isolate such factors as initial detention, depression storage, and depth of overland flow. To obtain the more complete phases of the hydrograph would require more data and analyses than is set forth in the following procedures.

It is recommended that at least the chief of each party become familiar with the literature on the subject of infiltration, most of which will be found in the transactions of the American Geophysical Union particularly during the past three years. Some of the more

pertinent literature is listed under the head of "Bibliography" which forms a part of this report.

Certain requirements are imposed upon any method and equipment which is suitable for rapid survey work under a wide diversity of conditions. To be entirely practicable the equipment must be highly portable, require only reasonable quantities of water, and should not be overly costly. It must be adjustable for a range of rainfall intensities, permit precise measurement of rainfall and run-off and be able to isolate such factors as canopy interception. It should be susceptible of installation with a minimum of soil disturbance. For these and other reasons the North Fork Infiltrometer has been selected for the 1939 field survey.

It should not be overlooked that infiltration is but one portion of the hydrologic cycle and that the collection of infiltration data for various parts of a watershed by any method does not provide all the information needed in formulating a comprehensive flood control program. It must be recognized, therefore, that much additional information is needed both for the application of infiltration data and for any satisfactory estimate of the hydrologic factors involved in flood flows.

The evaluation, adaptation, and use of the infiltration data should be by hydrologists and infiltrationists in consultation with the other technical men on the survey party.

II. Sampling Methods.

In general, the method of sampling will be to: (a) delineate homogeneous areas (or strata) within the watershed according to expected

rates of infiltration; (b) locate plots by dividing each stratum into 5 parts and spotting on a map 4 plots in each of these parts, selecting the exact location of the plot in the field; and (c) select plots for sampling special conditions.

A. Strata Delineation.

To select homogeneous areas or strata within a large watershed so that each strata will have approximately equal rates of infiltration requires close cooperation with all members of the Flood Survey party, along with sound judgment and experience on the part of the infiltration survey party leader. The first step in this process is to assemble all existing information concerning soils, land use, topography, and other factors which might influence infiltration. In some cases all this information will be available in the form of maps prepared by the survey party; in others it may be necessary to consult with the soils men, foresters, etc., and perhaps actually make a preliminary field survey.

The factors generally determining infiltration rates are the number, size and arrangement of openings in the soil. These in turn are influenced by such factors as soil moisture, land use, topography, and others. For infiltration surveys homogeneous areas in a watershed will be set up first on a basis of permeability of soil to water. For economy and practicability it is believed that 6 broad groups ordinarily will be adequate. As a guide in selecting these soil groups it is suggested that the soils of the two extremes of permeability be first selected and others of intermediate permeability be delineated as necessary.

The next step is to determine areas of homogeneous land use within each soil group. Ordinarily 4 such groups will be sufficient for the purpose of the infiltration surveys. Suggested types for land use delineation are: (1) forested; (2) cultivated; (3) pastured; (4) abandoned or idle. Obviously there are varying degrees of land use under each of these classifications.

The final consideration is topography, or more explicitly slope, which should be divided relatively into two classes, flat and steep. The actual slope percentages falling into each class will depend entirely on the specific area. For example, if you have set up an area of soils of medium permeability in agricultural use and the range of slope is from 0 to 10 percent, the flat slopes would range from 0 to 5 percent and the steep slopes from 5 to 10 percent. It is believed that slope strata will need to be delineated in relatively few surveys.

By the above process there will be set up, if all conditions are present in the watershed, 6 soil, 4 land use, and 2 slope groups, making a total of 48 strata for sampling. Since this number is too large for a practical infiltration survey for Flood Control Surveys, it must be reduced to about 20 strata. This should be done by drawing a chart or tabulating the various strata against the percentage of the entire watershed occupied by each strata, then eliminating all strata which are unimportant with respect to the flood control program. If, for example, the forested area is in good condition and occupies only 2 percent of the entire watershed, average infiltration rates would be insignificant with respect to the entire watershed; furthermore,

the area is not a silt or flood problem area and would not be recommended for improvement by an action program. If 20 strata are set up for a watershed each strata would represent 5 percent of the area, so in many cases, strata which occupy less than about 3 percent may be eliminated. Exceptions will be such areas from which data are needed for evaluating land use changes, or areas of less than 3 percent which constitute a distinct flood or silt problem. These cases are explained under "Special Conditions".

In some cases this process of elimination may not reduce the strata to be sampled to a reasonable number (tentatively set at about 20). Since the effects of slope on infiltration rates are usually considered less important than soil or land use, the slope classes may be eliminated. This is accomplished by first eliminating slope from strata where slope is known to be either of lesser importance or impractical of determination (e.g., forested areas in a range of all steep slopes and agricultural areas in mountainous country). Then, by eliminating slope from other strata, in order from the estimated least important to the most important slope effects until the desired number of sampling strata is reached.

It may be that 80 percent of a watershed will contain only one of the strata as herein defined; for example, a dense forest with a certain soil type. In such cases, the forested areas may be broken down into strata which have a direct bearing on flood problems, such a breakdown might include burned and unburned, grazed and ungrazed, or mismanaged and well managed forest lands.

It is well to keep in mind that the survey is to show average infiltration under existing conditions, as well as changes expected from an improvement program.

As a general proposition it should be recognized that it is better to obtain substantial information on the several more important features of a watershed than it is to obtain a smattering of information on all phases and subphases of the watershed. Once substantial information is obtained on the dominant features it is probable that satisfactory interpolations may be made for the features of lesser importance. For these reasons it may be necessary and desirable when time is limited to plan a minimum amount of work for those areas which are either very impermeable or obviously very highly permeable, as, for example, upon dense tight clay, deep sand, or upon exceptionally rocky areas. Areas having an infiltration of one-tenth inch per hour or less may be regarded as essentially too impermeable to permit much in the way of remedial measures to reduce the volume of flood water discharge unless these conditions are a result of land misuse. Areas having infiltration capacities under the wet condition in excess of 2 inches per hour may be regarded as very highly permeable. Once these facts are ascertained there is less need for extensive sampling than upon those areas intermediate between these two values.

Clearly, therefore, much depends upon the discretion and judgment of the chief of the party in organizing and planning the survey. Unique conditions undoubtedly will be disclosed either in entire watersheds or in their subportions and the exercise of much judgment obviously will be needed to meet and properly handle such situations.

B. Plot Location.

After the various strata for sampling are determined and drawn on a map, each stratum is subdivided into 5 sub-strata. This is done in such a way that each sub-stratum will have essentially the same shape and size. The stratum, and consequently each part, may or may not be contiguous.

In each of these 5 sub-areas for every stratum, spot on the map the position of 4 plots. The spotting is accomplished with due consideration given to roads and trails and to other economic and practical implications. The ideal location of the plots would be such that each would represent equal areas, but since this will seldom be practical, a distance of 1/2 mile is given as the minimum distance between plots.

The actual plot site is selected on the ground in the close vicinity of the spot marked on the map. It is so selected that the results of an infiltration run on the plot will be as nearly as possible representative of the field or local area in which it is situated. This method admits a certain amount of personal bias, but it is believed to be permissible in order to avoid sampling spots on which there are large trees, recent plow furrows, large exposed rocks, and other conditions that obviously should not be sampled.

C. Sampling Special Conditions.

The sampling methods as outlined above will give a reasonably accurate measure of the infiltration rates to be expected from the entire watershed. However, to be of most value to the Flood Survey, infiltration runs should be made to determine the

effects of forest litter, herbaceous vegetation, tillage practices, soil moisture, and freezing on infiltration rates. Where any special condition, such as the ones listed, are controlling factors they may be sampled as a stratum as previously described, but in most cases a few runs will be sufficient. The effect of forest litter will be made the subject of a special study elsewhere, so for the present the method of sampling in forested areas will be to remove the litter as described in "Operating Procedure" in all regular runs, but to make two additional runs with litter remaining in place for each forested strata set up for sampling. Low herbaceous vegetation such as grasses and crop lands may be handled the same way, that is, by making duplicate runs for unclipped vegetation. Where, in the course of the survey, enough data have not been obtained for a certain type of land use, let us say, and that land use is the logical remedial measure for a flood control problem, then it is necessary to obtain more runs. This sort of special sampling may often be necessary to solve certain definite problems.

Small areas of less than 3 percent of the watershed which constitute a distinct flood silt problem and for which there may be a remedial program should be sampled in the same manner as a complete stratum.

The multiple runs, 4 or 5 in number, as set up under "Operating Procedure," will yield data concerning optimum moisture conditions that may be sufficient for any survey. If winter conditions or flood seasons are controlling factors, and if land use changes may ameliorate these conditions, then additional samples shall be taken during the critical periods.

Sampling Error.

It has been said in the previous section that the number of samples to be taken in each of the 5 parts of a stratum is to be 4. This would mean 20 samples per stratum, which is a reasonable number. However, some simple calculations will have to be made in the field to determine if the correct number of infiltration samples have been taken and to permit the infiltration rate of a stratum to be expressed with its standard error.

The precision required in the infiltration surveys is an infiltration rate, based on wet runs only for a stratum which will be within the following percent of the actual in 19 out of 20 cases:

Average infiltration rate for a stratum	Permissible error
0.0 to 0.1 in. per hour	40 percent
0.1 to 0.5 " " "	30 "
0.5 to 1.0 " " "	25 "
Above 1.0 " " "	20 "

The statistical procedure to be employed can best be illustrated by the following example:

Suppose a 15-section sampling stratum (or block) had been surveyed with the following basic data resulting:

Plot Number	Infiltration Rate (Inches per hour)
1	3.2
2	2.5
3	3.3
4	2.5
5	4.0
6	3.1
7	2.8
8	2.8
9	8.0
10	7.2
11	3.5
12	3.0
13	7.3
14	7.9
15	2.8
16	2.4
17	7.7
18	2.1
19	7.5
20	6.5
Total	90.1
Mean	4.50

Calculations:

$$\text{s.d.} = \sqrt{\frac{\sum(x^2) - \frac{(\sum x)^2}{n}}{n-1}}$$

$$\text{s.d.} = \sqrt{\frac{503.51-405.90}{19}} = \sqrt{\frac{97.61}{19}} = \sqrt{5.13737} = 2.2666$$

$$\text{s.e.} = \frac{\text{s.d.}}{\sqrt{n}} = \frac{2.2666}{\sqrt{20}} = \frac{2.2666}{4.472} = .507$$

Where:

x = value for individual observation (3.2, 2.5, etc.)

$\sum$ = summation

s.d.= standard deviation

s.e.= standard error

n = number of observations

The standard error is a statistic that indicates the adequacy of sampling and the reliability of the mean. Its value is such that if the mean were again determined by repeat sampling of the same intensity the chances are 19 to 1 that the new mean would deviate less than twice the standard error from the previous determination. Thus repeated samplings of 20 samples of this hypothetical unit would provide mean infiltration rate values of $4.50 \pm$ 2 standard errors or 4.50 ± 1.01 in 19 out of 20 cases. The true value for the infiltration rate of this unit is probably within 22.5 percent of 4.50 ($1.01 \div 4.50$).

Since the specifications call for determination of the mean infiltration rate to within 20 percent of the true value where the mean is greater than 1.0 inches per hour, the permissible standard error is:

$$\text{permissible s.e.} = \frac{.20 \times 4.50}{2} = .45.$$

To determine the number of samples required to provide a standard error of .210, use is again made of the equation,

$$\text{s.e.} = \frac{\text{s.d.}}{\sqrt{n}}$$

$$\text{whence: } n = \frac{(\text{s.d.})^2}{\text{s.e.}}$$

Assuming the same standard deviation as before and substituting:

$$n = \frac{(2.2666)^2}{.45} = (5.037)^2 = 25.4$$

At least 5 or possible 6 additional samples will be needed.

The number of samples, permissible errors, and field check method have been specified tentatively to keep all infiltration surveys on a comparable basis. The limits of error may be out of line in either

direction, because no field data were available from which conclusions of expected accuracy could be drawn. It is anticipated that revisions to this part of the instructions will be made after sufficient field data have been analyzed. However, in the meantime, the methods as herein described will be followed and if cases arise in which an unreasonable number of samples are required, either (1) the "homogeneous" areas should be reclassified, or (2) the party should consult the headquarters office for future procedures.

IV. Operating Procedures.

A. Assembling and Transporting Equipment.

Upon receiving the equipment the field party shall check, inspect, and set up the apparatus for testing. Part of this test shall include determining a table of rainfall intensities which will result from the use of the various spray discs. This table will serve as a guide in applying precipitation rates in excess of the anticipated infiltration capacities. The table should be set up somewhat as follows:

Rainfall rates in. per hour	Disc no.	Pressure tank gage lbs. sq. in.	Line gage lbs. sq. in.
0.5 - 1.25	76	18 - 25	5 - 15
1.25 - 1.75	72	15 - 20	4 - 8
1.75 - 2.25	60	15 - 20	4 - 8
2.25 - 3.25	56	15 - 20	4 - 8
3.25 - 4.75	1/16	15 - 20	4 - 8
4.75 - 8.00	48	15 - 20	3 - 9
8.00 -12.00	42	15 - 20	3 - 10

When the nozzles and spray equipment are lined up all joints should be spot welded or soldered to prevent them from getting out of line. Before using the apparatus, the collector tank should be calibrated by actual volumetric measurements so that gage readings will represent exactly one third of the run-off. The specifications require the tank to be larger instead of smaller than actual dimensions to permit field correction by placing a steel rod or wire of the proper size vertically in the collector tank.

The equipment shall be kept clean because foreign matter may clog inlet pipes and dust or oily substances will change surface tension conditions on the galvanized iron surfaces.

All equipment shall be thoroughly packed into the truck in spaces especially prepared by the survey party in order to avoid damaging cutting edges and destroying alinement of the parts. A water tank consisting of 2 clean oil drums or a specially built rectangular tank holding approximately 90 gallons should be securely fastened in the truck. The arrangement shall be such that spaces are provided to carry the entire crew along with any baggage they may have from one headquarters to another. The truck body must be kept clean in order to prevent dust and oily materials from collecting on plot equipment.

Plot Installation.

1. Side and End Walls.

The first step in actually installing the infiltration equipment is to place the side walls in position on the sampling site with the spacer rods in place so that the sides are parallel to the direction of the steepest slope. They are then sunk into the soil to a depth (at least 1/2 inch at shallowest point) sufficient to prevent the inflow and outflow of surface run-off under the edges

of the plot. When in final position the rain splitting edges of the side walls should be exactly 12 inches apart. Following the same procedure the upper end wall is next installed. It should be placed in a perpendicular position so that the top of the end wall is against and even with the top of the side walls. The 6-inch end wall is used if the plot is installed on flat slopes or on hard soils; otherwise, the 7-inch one is used. This is to avoid unnecessary disturbance of the soil surface, particularly on the inside of the plot.

The best method of inserting the side and end walls in the soil is to first carefully remove sticks, small surface stones, and other objects which lie under the walls and prohibit setting them without disturbing the soil, then to cut a groove along the outside edges of the plot with a mason's trowel, simultaneously forcing the sides into the soil until the desired depth has been reached. If there is not a tight contact between the plot walls and soil surface on the inside of the plots after the sides are installed, the space should be filled with soil, carefully tamped in place by the trowel. It is also good practice to always tamp the soil firmly in place along the outside edge of the walls to completely eliminate the possibility of surface seepage into the plot. In very erodible soils, the spacer rods should be removed before the actual run because the rain drip from them increases erosion.

2. Baffle trough and cover.

The baffle trough is set in place between the side walls at a distance of exactly 30 inches (horizontal measurements) from the back wall. In order to allow free and unrestricted entrance of surface run-off, the cut-off on the inside edge of the baffle trough

should be placed in the soil to a depth sufficient to permit the spillway to be set slightly lower than the lowest level of the plot surface in immediate contact with it. If an opening exists between the baffle trough and the side walls, it can be closed with clay or earth to prevent leakage of surface run-off around the trough. The trough shall be set to a slope of about 1/4 inch in the 5-inch length to assure rapid transit of the water across it. The cover is then placed in position so that the upper or cutting edge is perpendicularly over the inflow lip of the baffle trough and exactly 30 inches (horizontal distance) from the inside top edge of the back wall. Table 1 of the appendix contains slope distances for various degrees of slope. These distances shall be measured and scribed on the plot walls as reference points to which the baffle trough and cover are set.

The run-off collector tank can be installed in any convenient position below the plot so long as it is leveled to permit accurate measurement of water depth, and connected with the drain pipe from the baffle trough in such a manner as to provide for the free flow of water from the trough to the tank. However, in order to prevent subsurface seepage from the wetted area into the hole dug for the collector tank, it should never be placed closer than 18 inches from the lower end of the plot. To facilitate draining and thus decrease instrument lag the collector tank should be placed as close to the 18-inch minimum as possible and low enough to obtain a minimum slope of 8 percent to the drain pipe.

3. Spray Equipment.

Before setting up the spray equipment it is necessary to make an estimate of the infiltration capacity of the soil so as to install spray discs which will produce a rainfall rate in excess of the infiltration capacity. It will require a certain amount of experience with the various soils and other conditions to make reasonable estimates, and until this can be done, the proper rainfall rate will have to be determined by trial and error. If the rainfall rate does not exceed the infiltration rate there will be no run-off and if the rainfall rate is just slightly higher than the infiltration rate, run-off will be delayed and may not take place for an hour or so. The table as made up according to the illustration under the heading "Assembling and Transporting Equipment," will serve as a guide in making this estimate and selecting discs for a particular run.

Two of the stakes equipped with adjustable supports for the spray apparatus are driven firmly into the ground on each side of the plot, normally at a position about at the lower end of the baffle trough cover. A third stake similarly equipped is driven into the soil about 12 inches below these and about 2 inches to one side of the center line of the plot. The sprinkling head is then placed in approximate position at a height of about 5 inches above the baffle trough cover, after which it is leveled, aligned, and tilted to the proper angle by adjustment of the supports.

A little experience will be required to judge the correct position of the supports as they depend somewhat on the rain intensity used and the slope of the plot being tested. On steeper slopes it will be necessary to operate the spray closer to the plot than on flat gradients. When low rainfall intensities are employed, other

conditions being the same, the sprays will need to be operated further from the plot and at somewhat less tilt than for higher intensities. The object is to apply rainfall evenly over the entire plot, but if for some reason this cannot be accomplished, the greater rainfall shall be applied toward the upper end of the plot. The rainfall distribution can be checked by placing a weathered board under the spray for a time suffieient to permit the formation of a rain pattern.

After the sprinklers are in place they are connected to the hose from the pumping outfit. The pump, when in use, should be set in a convenient position for operation.

4. Windbreaker.

Detailed instructions for setting up the windbreaker are not necessarily required, as the equipment will not fit together other than in correct position. Care, however, should be taken to set the sides parallel to and at an even distance from the sides of the plot. On steep slopes the frame should be set far enough back to prevent the end wall of the tent from intercepting the spray intended for the plot surface. The flaps at the front of the tent are constructed so that they can be extended over the sprinkling equipment when installed on the steeper slopes. It is important to eliminate wind effects as much as possible, and to this end it may sometimes be necessary to use additional stakes or take other precautions.

Operation.

1. Preparation of Sampling Sites.

After the plot has been installed and the equipment is in readiness for the infiltration runs, the aerial parts of the vegetation on the plot and border area should be carefully clipped to within about 1/4 inch of the soil to prevent interception losses. All undecomposed vegetal matter and litter down to the decomposed humus layer should likewise be carefully removed from the plot surface before

the infiltration runs are made. Where large vegetation, such as trees, are encountered, the plots should be offset just far enough to exclude their stems from the sampling area. Stems of brush and reproduction under 3 inches in diameter can be included in the plot area, but should be cut off nearly level with the soil.

Where runs are made without removing the litter, as explained under "Sampling Methods," the litter may be cut along the plot boundary with a pair of shears and the walls installed as previously described. In this case, always be sure that the plot walls extend down into the mineral soil. The same procedure may be followed for runs with grass or herbaceous vegetation unclipped. It must be remembered that in all cases the plot shall be installed with an absolute minimum of surface soil disturbance.

2. Soil Sampling.

It is desirable to obtain soil samples for an analysis of soil moisture and other soil conditions to be used as supplementary data for the infiltration surveys. It is, however, impractical to analyze the large number of samples that would be obtained if soil samples were taken for each infiltration run. Therefore, samples will only be taken immediately before each of the 4 or 5 runs on the plots set up as a test for each stratum, and before each of the two runs on one other plot within each stratum. The purpose of these test runs is explained under "Infiltration Runs," on page 26 .

Soil samples are to be taken with a standard soil auger or sampling tube and are to contain a minimum of 80 to 100 grams of air dry soil, depending on the density. They shall be taken in duplicate for each soil

horizon to at least 12 inches depth, placed in standard sample cans, and identified as described under "Field Recording." The samples shall be taken about 8 inches outside the plot boundary in the soil that is as nearly as possible representative of the soil within the plot boundary. This implies that, except for the sample taken before the initial run, all will be taken within the area wetted by the applied rain that has been protected from all modifying influences, such as footprints, etc. Since subsequent runs will be made on these plots it is necessary to thoroughly plug the hole made by the auger or sampling tube, and to be exceedingly careful in taking the samples so as to avoid unnecessary soil disturbance. If the samples are not to be weighted within 2 hours, the cans shall be thoroughly sealed with friction tape to prevent evaporation.

The equipment for obtaining and analyzing soil samples is not now available for the infiltration survey but in many cases can be secured from the S. C. S. regional office, or from the survey headquarters. In order to obtain soil samples, the party leader will be required to co-operate with the survey party and with the S. C. S. regional office to make arrangements for the use of equipment, or for actually obtaining and analyzing samples, or for a combination of these two. The method of analysis will depend largely on the equipment and personnel available. The most useful determinations are moisture content, and where feasible, volume weight, moisture equivalent, and organic matter determinations, the latter being permissible by the quick colormetric method. For volume weight determinations, special samples taken with a standard volume weight sampler are necessary. However, if the survey party has no supplementary personnel available for this work, the volume, weight and organic matter determinations may be omitted. Where samples are sent any distance for analysis they should be carefully packed and sealed to prevent evaporation.

3. Infiltration Runs.

After the plot installation has been checked for distances, possible leaks, etc., the rain pan is hung in place over the edges of the plot and the baffle trough cover placed in position so that the exposed area is exactly the same as the plot. Adhesive or Scotch tape may be used to close the unsoldered joints at the upper edge of the rain pan.

The canvas border cover is next placed completely around the plot to prevent wetting the adjacent area. In all cases the buffer area around the plot and within the windbreaker enclosure shall be treated exactly the same as the plot itself. To lessen the effects of walking on the buffer area, boards may be placed on the ground to serve as a walk. A test run shall be made to check the position of the sprinkling head for correct distribution of spray, adjust pressure regulator and spray nozzles, wet the equipment, and to see that there are no obstructions to free flow of water throughout the apparatus.

Pressures and nozzles should be regulated so that rainfall is applied as fine drops just large enough to avoid disturbances in delivery caused by air movements within the windbreaker. The rainfall should never be applied as fog, as the air turbulence caused by the spray when in operation so greatly affects the distribution of mist that it is difficult to duplicate the run accurately. After the spray equipment is properly adjusted, no changes should be made until after the calibration and actual infiltration runs for the particular set-up have been completed.

In making runs clear, clean water should be used and the filters, pressure regulator, and spray nozzles should be thoroughly clean. Best results will be obtained by maintaining from 15-25 pounds pressure in the pressure tank and adjusting the regulator so as to give the desired pressure in the delivery line. The pressure in the delivery line, as measured by the gage between the regulator and sprinkler head should be held constant during

runs by regulating the speed in pumping. If the pumping is regular and continuous throughout a run, there should be little difficulty in maintaining the operating pressure within 1/10 pound of constant.

Two 5-minute calibration runs to measure the rate of sprinkling should be made in connection with each infiltration run. The initial calibration run is made immediately before the infiltration run, using exactly the same pressures and sprinkling set-up to be employed in the infiltration test and the final calibration run. It must be remembered, however, that the rate of rainfall must at all times exceed the infiltration rate if valid measurements of the infiltration capacity of the soil are to be obtained.

The starting and ending time of the runs, which are made with the windbreaker tightly laced, should be recorded, and the total duration calculated. The rate of sprinkling, or applied rainfall, is determined by converting the differences between the point gage readings taken at the beginning and end of the run into inches depth per hour, as indicated under "Calibration Runs" on the form for recording results of infiltration.

In making calibration runs rainfall is first applied for a few minutes or until the water is flowing steadily into the collector tank. At the signal "time" the discharge

is stopped by means of the pinch valve on the rubber tubing at the collector tank end of the discharge line. A gage reading is immediately taken and the discharge line opened. At the end of the 5-minute period the last reading is taken, rainfall is then stopped and the system allowed to thoroughly drain.

After the initial calibration run has been completed, the rain pan and canvas border covers are removed and the actual infiltration test is started. The starting time of the run, which can be taken on an even minute, is the time that the stop cock on the pressure line is opened. The time that depression storage begins is the time at which small pools or a surface film begin to form on the plot surface, and the time run-off begins is the time at which water begins to move onto the baffle trough from the plot. These times are very important and must be accurately taken with a stop watch and recorded. The phenomena can be observed through the peek holes in the side of the windbreaker tent.

After flow appears at the collector tanks, gage readings are taken at stated time intervals by stopping the flow at a "time" signal long enough to obtain a point gage reading. Readings should be taken every 30 seconds until the run-off approaches a constant value, then every 1 minute for about 5 minutes, and finally every 5 minutes until it is definitely established that the run-off is

constant or nearly so. This will require runs of from 30 minutes, which will be the minimum run under any conditions, to around 2 hours or more for dry relatively permeable soils. The average run is estimated to be about 50 minutes.

Graph paper should be provided to plot in the field run-off rates against time to determine the length of run in cases where there is doubt concerning constant rates of run-off. This procedure will be especially useful for the first few runs on each strata.

After a constant rate of run-off is obtained the run is stopped at the end of a time period and the time at which rainfall ends is recorded. The observer then determines the time that run-off ends by closely watching the baffle trough for the last water that flows from the plot to the trough. Run-off sometimes ends very shortly after rainfall ends so that the observer must be in position at the end of rainfall. The last point gage reading is taken after the system has drained.

During the run, observations should be made to determine if the rate of rainfall is too high, that is, if it is producing erosion. If so, the run should be discarded and another run made at a different site with a lower rainfall rate. The minimum rate of rainfall to be applied is one that will yield surface run-off within 20 minutes after

rainfall begins, on most soils and within 60 minutes on the best soils, while the maximum rate is one that will produce no more than negligible erosion.

Following the infiltration run the rain pan and the canvas border cover are replaced and the final calibration run is made. The duration of the run and the procedure followed should be exactly the same as in the initial run. After the run has been completed the average rate of rainfall for the calibration runs is calculated and is used as a basis for determining the rate and volume of rainfall applied during the infiltration test. If the differences in the results of the two calibration runs exceed 2 percent of the mean, the data should be discarded and the entire test repeated. If the runs do not check within 2 percent or less, faulty technique, error in measurements, or improper functioning of the equipment are indicated.

When the runs have been completed, the plot and border areas should be covered to prevent surface evaporation. Before starting the succeeding runs, sufficient time should be allowed for the soil moisture to reach equilibrium and to permit normal soil swelling. This will ordinarily require about 24 hours, consequently this is taken as the minimum time interval between runs.

Enough water should be applied during the initial run or runs to bring the moisture content of the soil profile

to field capacity to a depth of at least 12 inches, and to deeper depths if possible. The second run should always be made on each plot after the moisture content of the soil has reached field capacity, as that is the soil moisture condition at which measurements of infiltration rates are most useful.

Ordinarily two runs, one at the existing soil moisture content at the time of the run, and one no less than 24 hours later, will be required for each plot. However, on the first plot of each strata sampled, additional runs should be made, also at no less than 24-hour intervals, to make certain that minimum infiltration rates are obtained. In some cases it may be necessary to make 4 or 5 runs to determine this rate. Infiltration rates for saturated soils involve other phenomena beyond the scope of the infiltration survey, but these extra runs obtained on each stratum may yield valuable information concerning saturated or nearly saturated conditions. At any rate, they will determine if the 24-hour interval between runs permits enough time for soil swelling and if minimum infiltration rates due to soil swelling and moisture content are being obtained. The minimum interval in some cases may have to be increased according to the results of these runs, or the quantity of water applied during the initial run may have to be increased.

V. Field Recording.

All field data will be recorded on two forms (which will be provided for the infiltration survey) and in some instances, on a standard cross-section sheet of letter size. The forms are attached hereto.

A. Sheet 1

The first sheet for each run is used for recording the physical conditions of the plot sampled and the results of calibration runs. The file designation has not as yet been set up so this space will be left blank for the present. On the line for "Location" the name of the watershed survey, the name of the nearest town, and the state shall be filled in. Under "Stratum" insert the number which has been assigned to the stratum in which the run is made. Similarly for "Plot no." Runs are lettered "A, B, C," etc., starting with "A" for the initial run and continuing to the last run. "Date" refers to the date of the run, and "Duration" to the length of the run.

The "Soil Type" if it can be locally determined, shall be inserted; if not, a brief description shall be given. "Erosion" refers to the general condition of the plot and consequently to the average condition in the immediate vicinity. It is recorded as gullies or sheet erosion, along with a description of the extent, such as very little, little, moderate, severe, or very severe. In the block provided for soil profile description the depths of each horizon and brief

description is required. For forest soils descriptions of the horizon shall be given separately from the A. The space to the right of this block is for general observations of any soil conditions which may affect infiltration. It is to be emphasized that soil characteristics shall be described with particular reference to porosity and structure, rather than to genesis and morphology. All descriptions under the heading "SOIL DESCRIPTION" are filled in after the last run on the plot is made. The actual area occupied by the plot is excavated with a spade to furnish this data.

The line after "CONDITION SAMPLED" is used to record a brief description of the stratum and general observations not provided for below the heading. Such observations as an estimate of the percent of plot area occupied by stone or other impermeable objects, clipped or unclipped vegetation, forest or crop conditions, an unusual amount of surface depressions, etc., are recorded. The "Slope" is measured along the side walls of the plot; the "Exposure" is the direction, approximated to the nearest one-half quadrant, of the center line of the plot in the direction from the uphill to the downhill end; and the "Position on slope", recorded as bottom, middle, or top, refers to the position of the plot with respect to the valley of the smallest drainage basin containing the plot. The "Vegetation type" should be described briefly, but accurately. For agricultural lands the crop is recorded, for pastures the type of grass

or other cover, and for forests the type shall be given as either hardwood, conifer, or mixed hardwood-conifer followed by the species of the tree under or near which the plot is situated. Two "Density" estimates are made, the first, aerial density, refers to the percent of the earth within the plot boundary covered by vegetation. In grass or low plant cover this may be made by looking directly down on the plot, but in the case of forest cover it must be made by looking up toward the sky. The intermediate conditions such as tall corn or brush cover present more of a problem but can be estimated by getting close to the ground and looking up. The second estimate, stem density, is made after the vegetation is clipped and in all cases can be made by looking directly down on the plot.

"Litter types" are determined by following the same outline as described for vegetation types. As examples, litter types may be a combination of timothy and white clover, or white pine and red oak. The more general type such as "grass" or "mixed" is recorded first. Litter "Density" is determined the same as stem density. The "Average depth" of litter is the average of several measurements of the litter layer within the plot boundary. Under "Land Use, Past and Present" is recorded all information that can be obtained from local residents, survey party members, and the recorder's own personal observations. This description should be as detailed and accurate as it is possible

to obtain within reasonable time limitations.

In general, the description under "Condition Sampled" is intended to present a reasonably accurate picture of the land conditions in the vicinity of the plot, as well as an accurate account of the conditions within the plot borders.

The blanks under "Calibration Runs" are filled in as described under "Operating Procedure" and need no further explanation.

In the space under "Notes" should be inserted any additional description of soils or conditions that may, in the opinion of the recorder, have a bearing on the infiltration or runoff rates of the plot. Observations and facts recorded here are extremely useful in analyzing the results of the run.

The first two columns in the block for "Soil Moisture Samples" are filled in at the time soil samples are taken and the remaining columns are for moisture determination tabulations. Soil samples are taken only at certain plots as described in the section "Soil Sampling Procedure".

The names of all members of the field party are recorded on the last line of sheet 1.

B. Sheet 2.

Sheet 2 of the field forms is used to record actual observed data and to make the necessary computations of runoff and infiltration.

The heading is completed from information obtained from Sheet 1, so that the two sheets can always be combined. Under column 1 the start of rain, storage, and runoff have been listed as the first observations to be taken, but other observations,

such as the end of rainfall and runoff are to be listed on the proper line. Any remarks pertinent to the operation of the equipment or to observed phenomena should also be recorded. Column 2 refers to the time at which observations or remarks are made or occur, and column 4 is the recorded cumulative gage readings. These three columns are the only columns of observed data, the remaining ones are computed. Columns 3 and 5 need no explanation as they are merely the differences between line 2 and line 1 recorded on line 2, etc. In column 6 is recorded the factor by which an increment in gage reading (column 5) is converted into a discharge rate in inches per hour for the time interval shown in column 3. Since the horizontal projection of the plot is always an area of 2.5 square feet and the area of the collector tank is one-third of this, or 0.8333 sq. ft., the formula for determining the conversion factor is:

$$\text{Factor} = \frac{\text{difference in gage reading}}{3} \times \frac{3600}{\text{time interval in seconds}}$$

The following table which may be supplemented and pasted on the recorder board gives values of the conversion factor for various time intervals:

Seconds	Factor	Seconds	Factor
15	80	180	6.667
30	40	240	5
45	26.667	300	4
60	20	360	3.333
120	10	420	2.857

The mean reading time in seconds, column 7, is used to plot runoff and infiltration rates against time. In this column is

recorded the time in seconds from the start of rainfall to the midpoint of the time interval as shown in column 3. The run-off in inches per hour, obtained by multiplying column 5 by column 6, is recorded in column 8. Column 9 is the difference between precipitation and runoff rates. Column 10 serves as a check on the arithmetic since adding columns 8 and 9 should give the constant rainfall rate. Totals as shown at the bottom of the sheet form a convenient check for the calculations.

Cross-Section Sheet

As mentioned under "Operating Procedure" it will often be necessary or at least helpful to actually plot in the field the results of certain runs in order to determine the length of run which will produce satisfactory results. The plotting, to consist of runoff rates versus time, will have to be carried along simultaneously with the field observations. Points so plotted will show the dispersion and the approach to constant runoff rates from which it may easily be determined whether or not the run has been continued long enough to obtain a good value for the infiltration rate. For this purpose letter size sheets of cross-section paper should be provided each field party. This graph, designated sheet 3 of 3 sheets, shall be attached to the other forms for the run and shall show the stratum, plot number, run number, and date of the run.

VI. Data Presentation.

A. Computations:

Computations required for the infiltration survey consist of determining infiltration rates and the standard error of mean infiltration values. It has been pointed out that for the purpose of the survey infiltration will be regarded as the difference between rainfall and runoff. These figures are obtained by performing the computations indicated on sheet 2 of the field forms (described under Field Recording). Column 9 shows these values. To determine the probable error of the mean value of the infiltration rate for a stratum involves computations as described under "Sampling Error". The individual values for an infiltration run are taken from plotted results as described under the next heading.

B. Graphic Presentation.

Rate of rainfall, rate of runoff, and the difference between rates of rainfall and runoff, as taken from the field forms, will be plotted graphically on coordinate paper 13 x 19 inches having 10 lines per inch. It is intended that the scale of plotting shall be such that the values of the individual points may be read directly from the graph. Usually the sheet provided will be sufficiently large to permit plotting to the largest scale that can be plotted on the sheet. However, in unusual cases, such as an exceptionally long run, it may be necessary to paste two sheets together. The initial and wet run curves or two successive wet run curves may be plotted on the same sheet.

In order to obtain consistent and comparable results, the infiltration rate for any run will be determined by the following method: first, draw the smooth curve which best fits the plotted points of infiltration rates; second, mark the point on this curve at which, in your best judgment, the curve flattens (point of apparent tangency); and, finally, find the average rate of infiltration for the next 20 minutes, which rate is used as the value of the infiltration rate for the run. The method is illustrated in the attached sample plotting sheet. This sheet also shows the runoff curve which is always plotted as the reverse of the infiltration curve. In all cases the title block shall be completely filled in with information which is largely taken from the field forms. The project number refers to the flood survey project.

In the final presentation of the data most emphasis will be given to the infiltration rate curves of the wet runs and the runs which provide what are deemed to be minimum values for any given homogeneous area or stratum. A summary showing the results from that stratum will be prepared by plotting on one sheet the 20 or more wet run infiltration rate curves for that stratum. This graph will therefore show the range of dispersion of the infiltration rates of the stratum. A similar summary chart for each stratum will comprise the essential features of the final presentation of data.

In connection with all of the above, it is obvious that it is of the utmost importance to have ample specific notes which describe the conditions where each determination is made. These notes, except for soil descriptions, should be prepared and recorded on the field forms before the actual infiltration determinations are made so that they may be objectively determined and entirely without personal bias. It should not be surprising should some discrepancies appear between expected and actually observed infiltration rates. Such cases frequently, however, provide very valuable information when subjected to subsequent study. Such subsequent analysis may disclose additional factors which need to be recognized and thus provide the basis for a continuing improvement in our knowledge of those which determine infiltration capacities.

C. Reports.

A concise descriptive report should be prepared to accompany the summary chart of each homogeneous area. This report will give the mean infiltration for the stratum together with the calculated standard error of the mean.

The descriptive report accompanying the summary charts will also show the specific characteristics of the stratum which apparently affect or determine the infiltration capacity. The report should also indicate ways by which the infiltration capacity may be increased. For example, it may appear from the data of an homogeneous area that somewhat higher infiltration rates have resulted from those sites where the organic

matter content is higher. Inasmuch as this indicates a possible practical control practice which may be recommended, such information is a valuable item and should be noted for possible use by the flood control staff. Direct comparisons between various important land use practices under conditions where soils and slopes are similar, of course will provide the best indications of treatments which may be recommended.

An overall summary comparing the different homogeneous areas should also be prepared. This summary will bring out differences in the effect of land use practices, and differences in the effect of soil structure. It will cite specifically areas of very low or very high infiltration capacities, indicating portions of the watershed in which the infiltration is too low to be of practical use in the control of flood water and conversely the areas which are practicable for treatment by land use practices. It will indicate the effect of water content of soil upon infiltration. In areas where freezing is important because floods occur under such conditions, the effect of freezing of soil will be shown. In general this summary report will be pointed toward a constructive viewpoint with reference to the possible recommendations which may be made with respect to the control of flood waters in the watershed and in its several components. Obviously, the summary report will deserve the utmost thought and careful consideration, as well as the consultation and advice of technicians working in the area.

VII. General Instructions.

In view of the complexity of the problem and the immaturity of the techniques pertaining to infiltration studies, it is apparent that much of the success or failure of an individual field survey depends upon the sound judgment of the crew personnel. A few suggestions are here offered to aid the infiltration party in obtaining useful data efficiently and economically.

A. Plot Location.

To avoid delay in the field work it is necessary for the party chief to actually locate the exact spots for infiltration runs well in advance of the time the party is expected to make the run. This implies that all of the planning associated with strata delineation as described herein will also be accomplished well in advance. At the time a plot is located in the field, local contacts with the land owner or resident should be made to obtain permission to make the runs and at the same time inquire as to the past and present use of the land. A schedule of operations will be helpful in keeping the crew operating smoothly without interruption due to not having plots located.

B. Crew Organization.

The most efficient crew is believed to consist of: one party chief of professional grade, one assistant of subprofessional grade, and one or two carefully selected laborers. During periods when the party chief cannot actually work with

the crew in making runs it may sometimes be necessary to get additional help. This will often be obtainable from the survey personnel but at other times it may mean hiring temporary labor for short periods. The availability of water and the accessibility of the plot will sometimes govern the size of the crew. Efficient crew organization depends largely on the administrative ability of the party chief, who will be responsible for the infiltration survey in its entirety.

C. Supervision.

The sub-committee or infiltration as set up by the flood control coordinating committee will be the supervisory body for all infiltration surveys. They will coordinate all field surveys so that results will be consistent and, so far as possible, comparable. This body will be available to answer questions arising in the field and to pass judgment on any problems, policies, unforeseen difficulties, or irregularities of such nature as to require a decision for which the party chief does not have authorization.

D. Travel.

It is anticipated that the infiltration party will travel considerably. The permanent headquarters will, of course, be the same as the Flood Control Survey's, but temporary headquarters will have to be established and changed frequently in the interest of efficient operation. In some cases where towns are too far away from the work, it will be necessary to make

arrangements to stay in the field for short periods. The party chief will plan in advance and make any necessary arrangements for stop-overs or establishing temporary field headquarters so as to efficiently carry out the infiltration surveys. He will also keep the Flood Control Survey Project Leader informed of the crew's progress and location.

E. Equipment.

It is required that all equipment be kept in first-class condition and to that end funds will be allotted. This money will also be available for local purchase of small tools and auxiliary equipment which are not provided, such as pipe wrenches, pliers, spades, etc. Wherever possible such equipment and supplies should be obtained from the Flood Control Survey or through its purchasing agency.

F. General.

As mentioned before, much depends on the party chief to organize and conduct a smoothly operating, efficient infiltration survey. The instructions as given herein have been prepared from the best available information at the time of writing but it is anticipated that revisions or additions will be necessary from time to time. Again it is emphasized that cooperation with the entire Flood Control Survey technical staff is essential in order to recognize all the problems and to accumulate all available data for their solution.

Appendix

TABLE 1

Table of Slope Distances

Percent Slope	Slope Distance ft.	Percent Slope	Slope Distance ft.
0	2.500	15	2.528
1	2.500	20	2.549
2	2.500	25	2.577
3	2.501	30	2.610
4	2,502	35	2.649
5	2,503	40	2.693
6	2.505	45	2.742
7	2.506	50	2.795
8	2.508	60	2.915
9	2.510	70	3.052
10	2.513	80	3.202
11	2.515	90	3.363
12	2,518	100	3.536

File

INFILTRATION SURVEY REPORT

Location: Washita Survey Chickasha, Oklahoma

Stratum 16 Plot No. 2 Run B Date May 13 '39 Time 10:40 a. Duration 45 Min.

SOIL DESCRIPTION: Soil Type Kirkland v.f.s.l. Erosion Sheet, very little

Soil profile description

5 in. - very fine sandy loam
3 in. - plow sole
- heavy plastic clay

Profile dense, with appreciable expansion and shrinkage; slippery when wet; subsoil tends to fracture along cleavage planes.

CONDITION SAMPLED Pastured to 3 or 4 inches, vegetation clipped to ½ inch.

Slope 6% Exposure South Position on slope Intermediate on long slope.

Vegetation: Type Wheat, pastured Density 20% reduced to 1% by clipping.

Litter: Type None Density -- Ave. depth --

Land Use: Past Plowed Aug. 1938, sowed to small grain. In former years cotton to excess.

Present Partial rotation small grain and sorghum frequently used as supplementary pasture, overgrazed.

CALIBRATION RUNS

INITIAL RUN: Starting time 10:02 Ending time 10:12 Duration 10 Min.

Gage rdgs.: Before run 2.66 After run 3.80 Diff. 1.14 Inches per hr. 2.28

FINAL RUN: Starting time 11:41 Ending time 11:51 Duration 10 Min.

Gage rdgs.: Before run 8.44 After run 9.67 Diff. 1.23 Inches per hr. 2.46

AVERAGE OF RUNS, Rainfall, inches per hour 2.37

NOTES: Farmer reports water stands on field following rains. Adjoining field yields 20 bu. wheat per acre with annual hail loss.

Soil Moisture Samples

(1) Sample No.	(2) Depth of Sample	(3) Wt. Can + Wet Soil	(4) Wt. Can + O.D. Soil	(5) Wt. Can	(6) Diff. (4)-(5)	(7) Diff. (3)-(4)	Percent P.O. (7)+(6)
Not							
Taken							

FIELD PARTY Marshall, Hobgood, Zwerman, Allen

File

Sheet 2 of 3 sheets
Date May 13, 1939
By E. O. Marshall

INFILTRATION SURVEY REPORT

Stratum 16 Plot No. 2 Run No. B

(1) Observations and Remarks	(2) Reading Time Hr.	Min.	Sec.	(3) Time Diff. in Sec.	(4) Gage Readings Cum.	(5) Diff.	(6) Conversion Factor	(7) Mean Reading time secs.	(8) Run-off (5)x(6)	(9) Prec.-Run-off= Prec.-(8)	(10) Prec. (8)+(9)
									Inches per hour		
Start rain	10	40	00		3.92			0			
" storage	10	40	37		--			37			
" run-off	10	41	20	80	--			80			
		42	57	97	4.02	0.10	12.371	128	1.237	1.133	2.37
		44	04	67	4.12	0.10	17.910	209	1.791	0.579	2.37
		45	12	68	4.22	0.10	17.647	277	1.765	0.605	2.37
		46	13	61	4.32	0.10	19.671	341	1.967	0.403	2.37
		47	16	63	4.42	0.10	19.047	403	1.905	0.465	2.37
		48	16	60	4.52	0.10	20.000	465	2.000	0.370	2.37
		49	15	59	4.62	0.10	20.388	525	2.034	0.336	2.37
		50	18	63	4.72	0.10	19.047	585	1.905	0.465	2.37
		51	16	58	4.82	0.10	20.689	646	2.069	0.301	2.37
		52	19	63	4.92	0.10	19.047	706	1.905	0.465	2.37
		53	17	58	5.02	0.10	20.689	767	2.069	0.301	2.37
		54	14	57	5.12	0.10	21.072	825	2.107	0.263	2.37
		55	13	59	5.22	0.10	20.338	883	2.034	0.336	2.37
		56	13	60	5.32	0.10	20.000	943	2.000	0.370	2.37
		57	13	60	5.42	0.10	20.000	1003	2.000	0.370	2.37
		58	12	59	5.52	0.10	20.338	1063	2.034	0.336	2.37
		59	09	57	5.62	0.10	20.172	1111	2.017	0.353	2.37
	11	00	07	58	5.72	0.10	20.689	1169	2.069	0.311	2.37
		01	07	60	5.82	0.10	20.000	1228	2.000	0.370	2.37
		02	08	61	5.92	0.10	19.671	1288	1.967	0.403	2.37
		03	01	53	6.02	0.10	22.641	1344	2.264	0.106	2.37
		04	02	61	6.12	0.10	19.671	1400	1.967	0.403	2.37
		05	03	61	6.22	0.10	19.671	1461	1.967	0.403	2.37
		05	54	51	6.32	0.10	23.529	1516	2.353	0.017	2.37
		06	53	59	6.42	0.10	20.338	1572	2.034	0.336	2.37
		07	43	50	6.52	0.10	24.000	1626	2.400	-0.030	2.37
		08	44	61	6.62	0.10	19.671	1681	1.967	0.403	2.37
		09	40	56	6.72	0.10	21.428	1739	2.143	0.227	2.37
		10	39	59	6.82	0.10	20.338	1796	2.034	0.336	2.37
		11	34	55	6.92	0.10	21.818	1853	2.182	0.188	2.37
		12	24	50	7.02	0.10	24.000	1906	2.400	-0.030	2.37
		13	31	67	7.12	0.10	17.910	1964	1.791	0.579	2.37
		14	26	55	7.22	0.10	21.818	2025	2.182	0.188	2.37
		15	34	68	7.32	0.10	17.647	2087	1.765	0.605	2.37
		16	33	59	7.42	0.10	20.338	2151	2034	0.336	2.37
		17	32	59	7.52	0.10	20.338	2210	2.034	0.336	2.37
		18	29	57	7.62	0.10	21.072	2268	2.107	0.263	2.37
		19	26	57	7.72	0.10	21.072	2325	2.107	0.263	2.37
		20	23	57	7.82	0.10	21.072	2382	2.107	0.263	2.37
TOTAL											

NOTE - Equal time intervals rather than equal run-off increments should be taken.

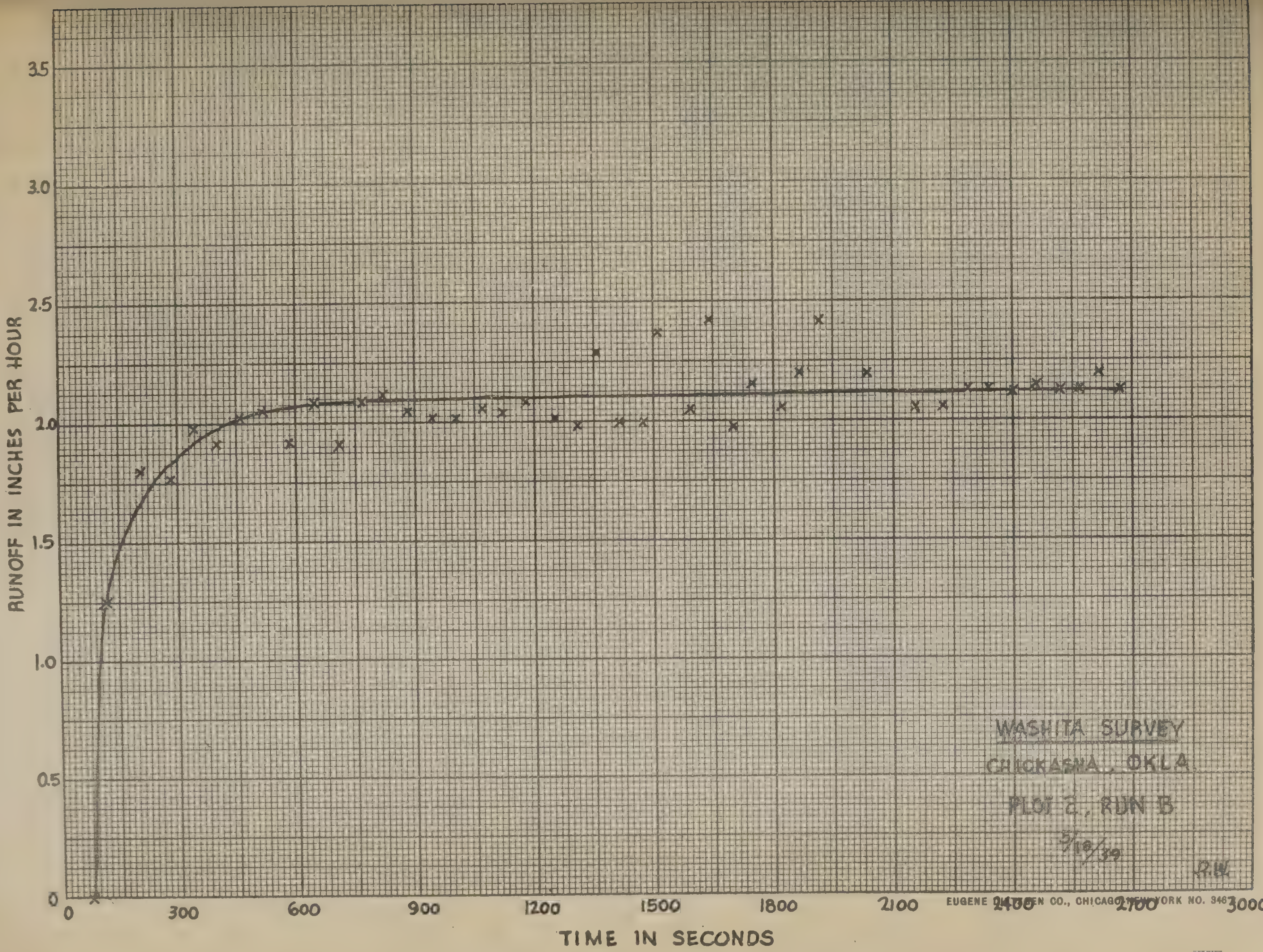
File

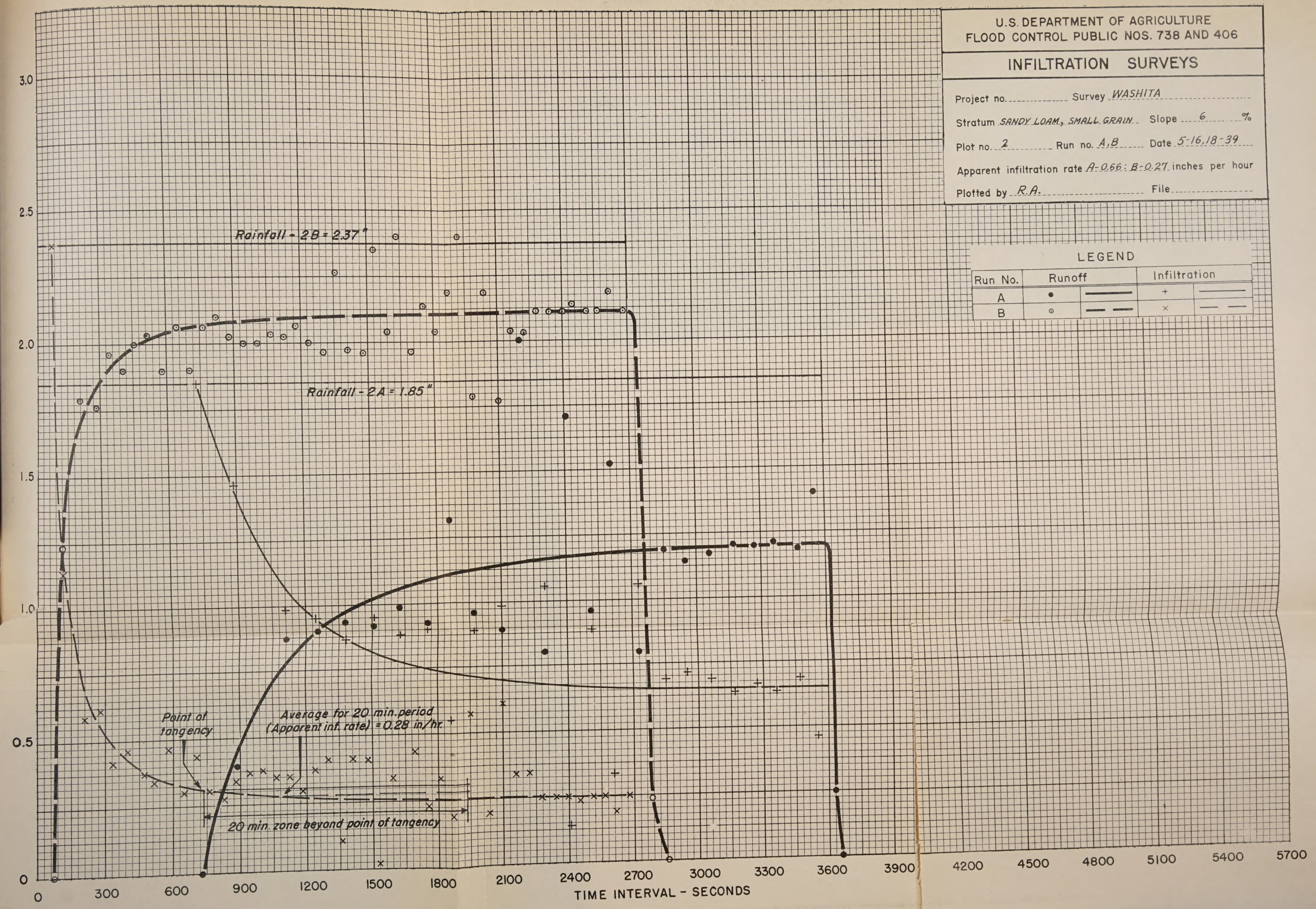
Sheet 3 of 3 sheets
Date May 13, 1939
By E. O. Marshall

INFILTRATION SURVEY REPORT

Stratum 16 Plot No. 2 Run No. B

(1) Observations and Remarks	(2) Reading Time Hr.	Min.	Sec.	(3) Time Diff. in Sec.	(4) Gage Readings Cum.	(5) Diff.	(6) Conversion Factor	(7) Mean Reading time secs.	(8) Run-off (5)x(6) Inches per hour	(9) Prec.-Run-off= Prec.-(8)	(10) Prec. (8)+(9)
Start rain											
" storage											
" run-off											
	11	21	19	56	7.92	0.10	21.428	2438	2.143	0.227	2.37
		22	16	57	8.02	0.10	21.072	2495	2.107	0.263	2.37
		23	13	57	8.12	0.10	21.072	2552	2.107	0.263	2.37
		24	08	55	8.22	0.10	21.818	2608	2.182	0.188	2.37
End rain	11	25	00	52	8.32	0.10	21.072	2662	2.107	0.263	2.37
" run-off	11	27	45	165	8.35	0.03	.727	2782	0.022		
End rain	11	25	00					2700			
" run-off	11	27	45					2865			
TOTAL	0	47	45	2865	8.35	4.33	--	2865	--	--	--


WASHITA SURVEY
CHICKASHA, OKLA.
PLOT 2, RUN B
5/18/39
R.W.
RUNOFF IN INCHES PER HOUR
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
TIME IN SECONDS



U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NOS. 738 AND 406
INFILTRATION SURVEYS
Project no.
Survey WASHITA
Stratum SANDY LOAM, SMALL GRAIN
Slope 6 %
Plot no. 2
Run no. A,B
Date 5-16,18-39
Apparent infiltration rate A-0.66; B-0.27 inches per hour
Plotted by R.A.
File
LEGEND
Run No.
Runoff
Infiltration
A
B
Rainfall - 2B = 2.37"
Rainfall - 2A = 1.85"
Point of tangency
Average for 20 min. period (Apparent inf. rate) = 0.28 in/hr.
20 min. zone beyond point of tangency
TIME INTERVAL - SECONDS
0
0.5
1.0
1.5
2.0
2.5
3.0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
4800
5100
5400
5700

BIBLIOGRAPHY

Bernard, Murill. Giving Areal Significance to Hydrologic Research on Small Areas. Headwaters Control and Use, U. S. Gov't. Printing Office, Washington, 1937, pp. 50-75.

Langbein, W. B. Some Channel-Storage Studies and Their Application to the Determination of Infiltration. Trans. Am. Geoph. Union, Part II, 1938, pp. 435-444.

Lowdermilk, W. C. Land-Use and Flood-Flows. Trans. Am. Geoph. Union, Part II, 1938, pp. 508-516.

Musgrave, G. W., and Free, G. R. Preliminary Report on a Determination of Comparative Infiltration Rates on Some Major Soil-Types. Trans. Am. Geoph. Union, Part II, 1937, pp. 345-349.

----------------------------------. Some Factors Which Modify the Rate and Total Amount of Infiltration of Field Soils, J. Amer. Soc. Agron., v. 28, no. 9, pp. 727-739, 1936.

Musgrave, G. W. The Infiltration-Capacity of Soils in Relation to the Control of Surface-Runoff and Erosion, J. Amer. Soc. Agron., v. 27, no. 9, pp. 727-739, 1936.

Horton, Robert E. Surface Runoff Phenomena. Part I, Analysis of the Hydrograph, Publ. 101, Horton Hydrologic Laboratory; Edwards Bros., Inc., Ann Arbor, Mich., 1935.

--------------------. Surface Runoff Control. Headwaters Control and Use, U. S. Gov't. Printing Office, Washington, 1937, pp. 16-41.

--------------------. Determination of Infiltration Capacities for Large Drainage-Basins. Trans. Amer. Geoph. Union, Part II, 1937, pp. 371-385.

Sherman, L. K. Determination of Infiltration Rates from Surface Runoff. Trans. Amer. Geoph. Union, Part II, 1938, pp. 430-434.

Veihmeyer, F. J. Bibliography, Physics of Soil Moisture. Trans. Amer. Geoph. Union, Part I, 1938, pp. 340-342.